How Fundamental is Embodiment to Language Comprehension? Constraints on Embodied Cognition

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Abstract

Many studies have shown that language comprehension can activate embodied representations. Whether these studies have shown that embodiment is a necessary and sufficient condition for language comprehension, or whether embodiment can be a matter of depth of processing is a question that has not been answered. Three experiments examined how iconicity and semanticity affected reaction times. Following Zwaan and Yaxley (2003) word pairs were presented simultaneously, one above the other in either an iconic (*branch* above *root*) or reverse-iconic (*root* above *branch*) presentation (Experiment 1 and 2) or next to each other (Experiment 3). Half of the materials had a strong semantic relation, the other half a weak semantic relation, measured by word associations. Following Zwaan and Yaxley's (2003) study, a semantic judgment task yielded differences in RT for iconicity and semanticity. However, a (shallow) lexical decision task yielded the same differences for semanticity but not for iconicity. Horizontal presentation of the items again yielded semanticity but not iconicity differences. Moreover, in all experiments medium to large effect sizes were obtained for semanticity, and negligible effect sizes for iconicity. These findings suggest that embodied information like iconicity only receives enough activation when language is processed deeply.

Keywords: embodied cognition, statistical language processing, latent semantic analysis, language comprehension, depth of processing, semantic judgment, lexical decision

Introduction

Over the last decades the discussion whether language conveys meaning through symbolic or embodied representations has livened up, with different sides arguing in favor of one and against the other approach. According to a symbolic account of language comprehension words derive their meaning through associations with other words. According to an embodied account words cannot retrieve meaning through symbolic associations but instead must constantly be grounded in the physical world. Whereas symbolic accounts dominated cognitive psychology in the seventies and eighties (Fodor, 1975; Kintsch, 1973; Pylyshyn, 1984), the last decade seems to be dominated by embodiment theories pointing out weaknesses in a strictly symbolic accounts (Barsalou, 1999; Glenberg, 1997; Pecher & Zwaan, 2005; Pulvermüller, 1999).

Many studies have argued that embodiment is fundamental to cognition (Wilson, 2002). Whereas in these studies *fundamental* is supposed to be synonymous with *necessary*, this study shows that *fundamental* is synonymous with *deep-rooted* showing that embodiment processes aren't always activated. In particular they are exhibited in tasks requiring deep processing but not in shallow tasks.

Embodied Language Comprehension

A wealth of evidence has accumulated that language conveys meaning through embodied objects and experiences (Boroditsky, 2000; Dahan & Tanenhaus, 2002Glenberg & Kaschak, 2002; Matlock, Ramscar, & Boroditsky, 2005; Pecher, Zeelenberg, & Barsalou, 2003; Pecher & Zwaan, 2005; Zwaan, Stanfield, & Yaxley, 2002; Wiemer-Hastings & Xu, 2005). These findings show that cognitive processes cannot be solely symbolic, deriving meaning from word associations. However, these studies do not annihilate a symbolic account of language processing, because participants deal with nonlinguistic stimuli (pictures) or actions (motor) that could cue embodied processes. In order to argue that language comprehension *must* involve embodied processes a strictly linguistic task is needed. One of the most straightforward experiments showing that linguistic stimuli yield embodied representations is Zwaan and Yaxley (2003). They use the supposedly embodied knowledge of the spatial configuration generally specifying the location of two objects in space as a way of varying the location of two words referring to these objects. Two words were either displayed in their iconic order, like when the word *attic* is presented above the word *basement* or in the reverse iconic order (*basement* above *attic*). When participants made semantic similarity judgments on each of the word pairs, reaction times were higher in the reverse-iconic condition than in the iconic condition, suggesting that comprehenders activated perceptual representations of the referents of the word pairs.

Statistical Language Comprehension

Statistical language comprehension gained impetus with computational models like Latent Semantic Analysis (LSA; Landauer & Dumais, 1997) and Hyperspace Analogue to Language (HAL; Lund & Burgess, 1997). Theories behind these models have claimed to provide a solution to Plato's problem, the psychological problem of how humans observing a relatively small set of events can construct knowledge representations that are adaptive in a large, potentially infinite variety of situations (Landauer & Dumais, 1997). Techniques like Latent Semantic Analysis and Hyperspace Analogue to Language do this by mapping initially meaningless words into a continuous high dimensional semantic space, which can be seen as simulating cognition. Because stimuli are paired based on their contiguity or co-occurrence, this process is analogous to psychological classical conditioning. Like language comprehension, memory for the initial local associations (surface structure) becomes memory for more global representations (central meaning). These techniques can thereby be seen as a theory of knowledge representation, induction and language acquisition.

Indeed, there is considerable evidence that the performance of LSA correlates with human performance (Graesser, McNamara, Louwerse & Cai, 2004; Landauer & Dumais, 1997; Landauer, Foltz & Laham, 1998; Landauer, McNamara, Dennis & Kintsch, 2007).

Symbol Interdependency

In a nutshell, there is evidence that language comprehension involves embodied representations that prima facie cannot be explained statistically, and there is evidence that results from language comprehension can be explained with statistical techniques. These pieces of evidence don't necessarily contradict one another.

For instance, Barsalou (1999) argued that statistical approaches like LSA can explain findings in a post-hoc fashion, make very few predictions about cognitive phenomena and are unfalsifiable. Instead, Barsalou argued, words always need grounding. Landauer and Dumais (1997) on the other hand argued that a few words need grounding, but referential meaning can generally be inferred from contextual statistics of usage.

Elsewhere (Louwerse, 2007; Louwerse, et al., 2006) we proposed a Symbol Interdependency Hypothesis. Following theories by Peirce (1923) and Deacon (1997) we argued for a hierarchy of signs whereby symbols can be linked to one another, as well as to their non-linguistic referents. Symbols are thus coded twice, through other symbols as well as through their referents. Comprehenders can benefit from the rich interrelations between symbols, because language serves as a symbolic short-cut to meaning. However, when more than a short-cut is needed fully specified interpretations emerge through embodied representation.

These hypotheses imply a distinction between shallow (underspecified and incomplete) and deep (specified and complete) language processing. Moreover, they imply that language processing is typically shallow. Indeed, there is evidence that semantic anomalies in texts often go unnoticed (Barton & Sanford, 1993; Van Oostendorp, Otero & Campanaro, 2002). For language processing all that (usually) counts is "good enough representations" (Ferreira et al., 2002).

This paper hypothesizes that semantic associations, but not embodied representations are essential to representations good enough for usual language processing. If this is the case, a deep language comprehension task should elicit effects for embodiment, whereas a shallow comprehension task should not. At the same time, both comprehension tasks, shallow and deep, should elicit effects for semantic associations. Moreover, if these semantic associations are prevalent, the prediction is that the effect sizes are larger for semantic than for embodiment factors.

Two RT experiments investigated the prevalence of embodiment and semanticity, one being a deep-level processing task (semantic judgment) the other a shallow-level processing task (lexical decision). Both experiments used the procedure and stimuli from Zwaan and Yaxley (2003). Moreover, in order to address Barsalou's (1999) concern of post hoc explanations for semantic associations, we added stimuli that did not have an iconicity relation but, akin to the iconic items, were also varied on semantic relatedness.

Experiment 1

Participants

Sixty undergraduate students from the University of Memphis participated for Psychology course credit.

Design

Two factors were of interest in this experiment: 1) iconicity (iconic and reverse-iconic), 2) semanticity (high and low semantic), as described in detail in the Materials section. These factors were varied within subjects and items.

Materials

Fifty-six experimental items were used, with 28 word pairs with an iconicity relation and 28 word pairs without such a relation. All 28 iconicity word pairs were taken from Zwaan and Yaxley's (2003) pool of 71 experimental pairs, which were designed on an intuitive basis. The selection was made by taking those items from the pool that had the 14 highest and the 14 lowest semantic associations as determined by Latent Semantic Analysis (LSA), a method also used by Zwaan and Yaxley (2003) to control for semantic relatedness.

In addition, 28 non-iconic items (e.g. *shark-fish*) were added from the Edinburgh Association Thesaurus (Kiss, Armstrong, Milroy & Piper, 1973), whereby a target word was paired with an associated word such that it would not evoke an obvious iconic relation. The semantic relation of the two words was again determined by LSA. The average cosine for all high semantically related words was .67 and .08 for low semantically related words. An overview of the items used is presented in Table 1.

Note that the nomenclature used in this paper is as follows: *iconic* items consist of the Zwaan and Yaxley items (*attic-basement*) and can be presented in an iconic order (*attic* above *basement*) or a reverse-iconic order (*basement* above *attic*). In addition, *non-iconic* items do not have this spatial iconicity relationship (e.g. *web-spider*).

The presentation for all 56 word pairs was counterbalanced. For instance, a high-semantic iconic word

Table 1. Experimental items used in Experiments 1 and 2.

iconic		non-iconic	
high semantic	low semantic	high semantic	low semantic
deck - mast	mound - pitcher	beach - sand	cancer - womb
runway - airplane	mattress - sheet	table - chair	nut - tiger
radio - antenna	porch - handrail	trees - forest	union - hat
floor - ceiling	doughnut - icing	finger - hand	stone - head
ankle - knee	lawn - sprinkler	cloud - sky	sex - car
launchpad - rocket	highway - billboard	face - nose	world - cup
railroad - train	lobby - penthouse	web - spider	rings - curtain
toast - jam	coaster - glass	music - piano	spurt - fountain
track - runner	fireplace - mantle	girl - boy	spray - cork
beard - moustache	trailer - boat	fish - shark	suit - card
pants - sweater	beer - foam	bullet - gun	line - branch
candle - flame	trail - hiker	dentist - teeth	snake - belt
moat - castle	coffee - froth	pot - pan	organ - pipe
box – lid	street - stoplight	hawk - eagle	radiator - grill

Note: Iconic items are taken from Zwaan & Yaxley (2003)

pair appeared in its iconic order (*attic* above *basement*) in one list and in the reverse-iconic order (*basement* above *attic*) in the other. Similarly, the non-iconic word pairs were counterbalanced, but without the theoretical implications iconicity word pairs had.

In addition to the 56 experimental word pairs 56 non-word filler items were used, half word and non-word pairs, half non-word pairs. As with the real word pairs, order of the words was counterbalanced.

Procedure

Participants were seated in front of a 17'' computer screen. The experiment was run on PCs using the E-Prime software. They received instructions to judge the semantic relatedness of word pairs presented to them. The words were presented in black Courier font, font size 18, on a white background and subtended at most 1.35º of vertical visual angle from a distance of 48 cm. An asterisk (*) was presented at the center of the screen, after 1 second followed by a word pair. Participants pressed as soon as possible whether items were similar or not similar in meaning. After five practice items, participants had the opportunity to ask any question, after which the experiment started.

Results and Discussion

Results for all filler data (non-word combinations) were removed from the analysis. RTs are given in Figure 1.

ANOVAs were run with Iconicity and Semanticity as the main factors, each with two levels, whereby subjects (F_1) and items (F_2) were treated as random factors respectively. The first analysis of interest concerned the replication of Zwaan and Yaxley's (2003) finding that reverse iconic order yielded higher reaction times than the iconic order. An ANOVA with iconicity as the independent variable showed that the items involving reverse iconic word pairs yielded longer RTs than the iconic word pairs, though with a marginally significant effect in the by-items analysis (F_1 (1, 59) = 6.55, p = .013, *MSE* = 18078; F_2 (1, 27) = 3.15, p = .087, *MSE* = 9110, *Cohen's d* = .09). Despite the fact that a different set of 28 word pairs was selected from the Zwaan and Yaxley (2003)'s experiments – those with the highest and lowest semantic association from the large pool of 71 word pairs, and despite the fact that non-words were used as filler items, their findings were replicated. Iconicity has processing benefits in semantic similarity judgment tasks.

Not surprisingly, no order differences were found for the non-iconic items.

Non surprisingly, the semanticity of the items pairs also yielded significant differences, both for the iconic items F_1(1, 59) = 24.71, p < .01, *MSE* = 31475; F_2(1, 27)= 4.66, p = .04, *MSE* = 16759, *Cohen's d* = .62) and the non-iconic items (F_1(1, 59) = 24.73, p < .01, *MSE* = 52149; F_2(1, 27)=12.59, p < .01, *MSE* = 13857, *Cohen's d* = .84), with the semantically similar words leading to shorter RTs.

The results of the semantic judgment task replicated Zwaan and Yaxley's (2003) iconicity effect. The results also show a semanticity effect. In fact, only negligible effect sizes were found for iconicity (*Cohen's d* = .09), whereas medium to large effect sizes (*Cohen's d* = .62-.84) were found for semanticity,

Experiment 2

Experiment 2 was identical to Experiment 1, except that the instructions to participants were not to make semantic judgments as in Experiment 1, but to make a lexical decision whether word pairs consisted of words or non-words. If embodiment is fundamental to language comprehension, iconicity effects should be obtained. If embodiment is a deep process of language comprehension, semanticity differences are expected to be found, but no iconicity effects are expected.

Participants

Fifty-three undergraduate students from the University of Memphis participated for Psychology course credit. None of the students participated in the previous experiment.

Design and Materials

Design and stimuli were identical to those in Experiment 1.

Procedure

The procedure was identical to Experiment 1, except that the instructions now asked participants to judge whether the word pair consisted of two words or that there was at least one non-word.

Results and Discussion

Results are presented in Figure 1. No significant differences were found between iconic and reverse-iconic order (F_1 (1, 49) = .08, p = .78, *MSE* = 17226; F_2 (1, 27) = .064, p = .802, *MSE* = 14840, *Cohen's d* = .02).

On could argue that the absence of an iconicity effect could indicate that no language processing took place in the lexical decision task. But that argument is not supported by the semanticity findings. As in Experiment 1, semanticity yielded a difference for both the iconic (F_1 = 14.71, p < .01, *MSE* = 23094; F_2 = 2.98, p = .09, *MSE* = 11717, *Cohen's d* = .28) and the non-iconic items (F_1 = 38.18, p < .01, *MSE* = 17077; F_2(1, 27) = 6.9, p = .01; *MSE* = 12265, *Cohen's d* = .39).

Again, not surprisingly, no order differences were found for the non-iconic items. Iconicity had an effect on RTs in semantic judgment, but not in lexical decision tasks. Semanticity, on the other hand, had an effect on RTs in both semantic judgment and lexical decision tasks.

So far we argued that semantic judgment is a deeper processing task than lexical decision, because the latter is a prerequisite for the former. That is, without identifying that a string of letters is a word, there is little semantic judgment that can take place. Consequently, RTs for semantic judgment are expected to be longer than for lexical decision, a prediction confirmed by the current findings.

But Zwaan and Yaxley's argument in favor of perceptual simulation was not only based on reverse-iconic pairs yielding longer RTs than iconic pairs, but also on obtaining this effect for word pairs presented vertically and not horizontally. The argument in this paper has been that semanticity is more fundamental to language comprehension. This is supported by the effect for both the iconic and non-iconic items. However, if semanticity is fundamental for language comprehension, semanticity should also be obtained for a horizontal presentation of the word pairs, regardless of the task (semantic judgment or lexical decision). Iconicity, on the other hand, is not expected to yield differences, because the iconicity concerns the vertical dimension, and not the horizontal one. These predictions were tested in Experiment 3.

Experiment 3

Participants

36 undergraduate students from the University of Memphis participated for Psychology course credit. None of them participated in the previous experiments.

Design, Materials and Procedure

Design, stimuli and procedure were identical to those in Experiment 1 and 2, except that all items were presented horizontally instead of vertically, whereby half of the subjects participated in the lexical decision and half of the subjects participated in the semantic judgment task.

Results and Discussion

RT results are presented in Figure 1. Analogous to Zwaan and Yaxley (2003) no iconicity effect was found, neither in the semantic judgment (F_1 (1, 17) = .03, p = .86, *MSE* = 65217; F_2 (1, 27) = .001, p = .97, *MSE* = 59913, *Cohen's d* = .02) nor in the lexical decision task (F_1 (1, 17) = 1.38, p = .26, *MSE* = 15139; F_2 (1, 26) = .47, p = .5, *MSE* = 53831, *Cohen's d* = .09). On the other hand, semanticity yielded significant differences for both the iconicity items and the non-iconicity items in both semantic judgment (iconicity items: F_1 (1, 17) = 5.39, p = .03, *MSE* = 129885; F_2 (1, 26) = 8.08, p < .01, *MSE* = 57328, *Cohen's d* = .3; non-iconicity items: (F_1 (1, 17) = 25.04, p < .01, *MSE* = 15836; F_2 *(1, 26)* = 23.13, p < .01, *MSE* = 115975, *Cohen's d* = .69) and the lexical decision task (iconicity items: F_1 (1, 17) = 9.9, p < .01, *MSE* = 21434; F_2 (1, 26) = 3.97, p = .05, *MSE* = 30974, *Cohen's d* = .27; non-iconicity items: (F_1 (1, 17) = 26.64, p < .01, *MSE* = 120860; F_2 (1, 26) = 4.37, p < .05, *MSE* = 59103, *Cohen's d* = .37).

No order differences were found for the non-iconic items.

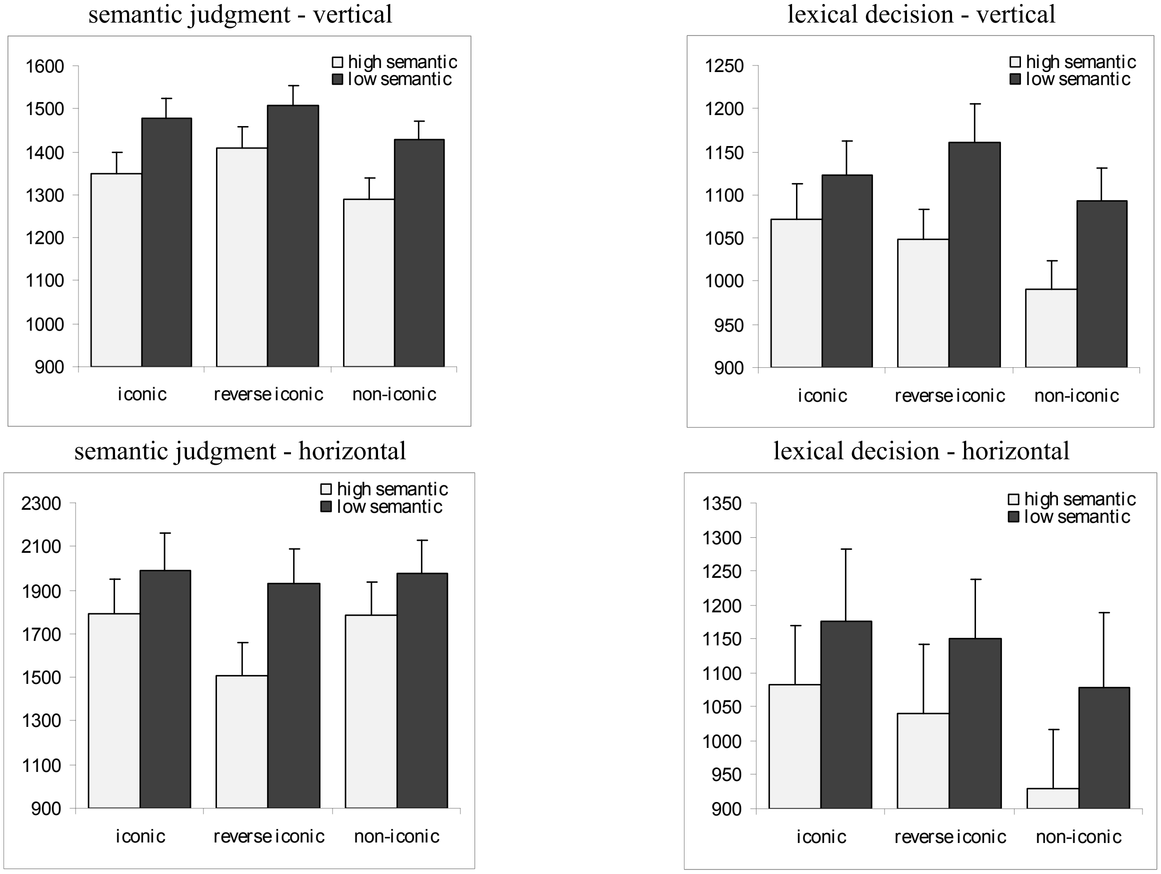
As expected, no iconicity effects were found for the horizontal presentation of the iconic word pairs in the semantic judgment task. This confirms Zwaan and Yaxley's (2003) results. Iconic word pairs presented vertically did yield RT differences, but iconic word pairs presented horizontally did not.

The question to be addressed next is how fundamental iconicity and semanticity are for language comprehension? The results suggest that the answer is that it depends on the depth of processing required by the task. The semanticity factor displayed reliable and substantial effects in all circumstances, while the iconicity factor only manifested itself in the deepest task (the semantic judgments) when the spatial configuration was consistent with the iconicity factor (i.e., vertical).

General Discussion

There is no doubt that language comprehension is ultimately embodied (De Vega, Glenberg & Graesser, in press; Pecher & Zwaan, 2005). We do not know of any studies that would doubt that embodiment is deeply rooted in language comprehension. However, we do cast doubt on embodiment

Figure 1. Average RTs in function of iconicity and semanticity.



being always *necessary* to language comprehension. The results of the three experiments presented in this paper support that doubt.

Semantic judgment and lexical decision tasks yielded significant differences in RT for words with low versus high semantic relationships, as determined by LSA. These differences were found for the iconic word pairs as well as the non-iconic word pairs. Moreover, effect sizes were small to large. Iconicity on the other hand only yielded a significant difference in a semantic judgment task with a vertical presentation of the word pairs, but not in a lexical decision task. Moreover, the effect size for iconicity in the semantic judgment task was negligible.

We have explained these results by depth of language processing. We argued that lexical decision is a prerequisite for semantic judgment, and consequently semantic judgment is a deeper processing task than lexical decision. Stimuli manipulations yielding differences in RT for both lexical decision and semantic judgment can thus be considered more fundamental to language comprehension than manipulations only yielding effects in semantic judgment tasks. Moreover, manipulations yielding differences in a semantic judgment task but not in a lexical decision task are claimed to be associated to deep processes of language comprehension.

This explanation of course only holds if both lexical decision and semantic judgment tasks are considered natural language processing tasks. In fact, the argument could be made that lexical decision tasks may not accurately reflect normal language processing (Balota, Paul, & Speiler, 1999), so *double* lexical-decision tasks like the ones used in the present studies should subsequently be considered extremely unnatural. Such a conclusion however is not warranted by the data. Semantic judgment and lexical decision yielded identical patterns for semanticity factors suggesting that our double lexical decision task yielded results also found in default comprehension tasks.

In addition to the iconic stimuli used in these experiments, we also used words that were randomly selected and combined into word pairs on the basis of a high versus low LSA cosine. We ruled out that these items had an iconic relationship, and it is not clear how the low-semantic relation word pairs are different from the high-semantic relation word pairs in terms of embodiment. Addressing Barsalou's (1999) concerns referred to earlier, these items allowed for a priori predictions and explanations, are falsifiable and therefore illuminating. In fact, differences and effect sizes for semanticity were consistent for horizontal and vertical presentation of stimuli, for semantic judgment and lexical decision task, and for both iconic and non-iconic items.

Do we argue that LSA explains how the mind works? No. Do we argue that evidence in favor of embodied representations should be dismissed? No. Do we argue that symbols don't need grounding? No. Instead, we have argued here that language comprehenders rely on semantic associations which are part of "good enough representations". When comprehenders are involved in deeper language processing tasks, embodied representations emerge. The depth of language processing has been defined in this paper based on the experimental task, but could also be defined in term of memory load, cueing linguistic stimuli with non-linguistic stimuli, or specificity of interpretation. Future research should reveal these constraints on embodied cognition.

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